

# Cable Lore

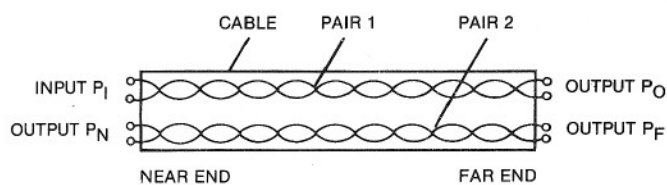
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## CROSSTALK

Excessive crosstalk is responsible for the phenomenon we have all experienced while using a telephone, that is, the hearing of someone else's conversation while carrying on our own. Crosstalk in a telephone cable is defined as a measure of the unwanted signal induced in a "disturbed" pair by a signal on a "disturbing" (signal carrying) pair. Crosstalk increases at higher frequencies and is therefore more troublesome when transmitting high speed digital signals than when transmitting lower frequency audio signals.

To better understand Crosstalk, let us examine two twisted pairs of a multipair cable as shown below.



In the illustration,  $P_I$  represents the "disturbing" power,  $P_N$  the "near end" crosstalk power,  $P_O$  represents the "disturbing" power minus any power loss in pair 1 and  $P_F$  represents "far end" crosstalk power. Signal power levels are typically in the milliwatt ( $10^{-3}$  watt) range in the disturbing pair. The power level of the crosstalk signal in the disturbed pair is usually

in the micro ( $10^{-6}$ ) to nanowatt ( $10^{-9}$  watt) range.

Engineers usually express crosstalk in terms of decibel (dB) units of loss in the crosstalk path. A decibel is a unit of measurement that is used to quantify the ratio of power in the disturbed pair to the power in the disturbing pair. Near end crosstalk loss (abbreviated NEXT) and far end crosstalk loss (FEXT) expressed in decibels are given by the following mathematical expressions:

$$\text{NEXT} = 10 \text{ LOG } (P_N/P_I)$$

$$\text{FEXT} = 10 \text{ LOG } (P_F/P_O)$$

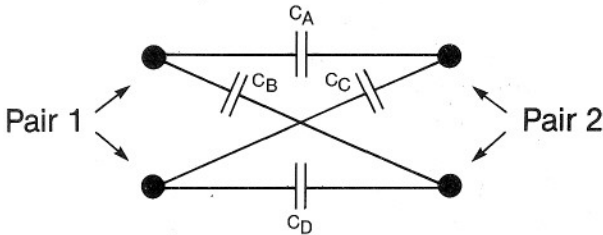
Larger crosstalk loss values are better, since a larger number represents greater loss in the crosstalk path from the disturbing to the disturbed pair.

### Crosstalk Mechanisms

Crosstalk results from electromagnetic coupling between twisted pairs in a telephone cable. This electromagnetic coupling consists of two components – capacitive and inductive (magnetic) coupling. Both are fundamental natural processes and cannot be eliminated but, with proper cable design can be controlled. This is primarily accomplished by minimizing pair-to-pair capacitance unbalance and inductive coupling between pairs.

## Pair-to-Pair Capacitance Unbalance

Pair-to-pair capacitance unbalance is caused by small variations in capacitance between the four conductors comprising two twisted pairs. These capacitances are illustrated below.



Each capacitor shown represents the total capacitance between any two conductors. This capacitance depends on insulation thickness, dielectric constant of the insulation, conductor-to-conductor spacing and the dielectric constant of any filling compound used. Mathematically, capacitance unbalance ( $C_U$ ) is defined as:

$$C_U = (C_A + C_D) - (C_B + C_C)$$

In telephone cables, pair-to-pair capacitance unbalance typically ranges from 0 to 50 picofarads ( $10^{-12}$  farads) per 1000 feet (305 meters) of cable. Other unbalances, such as pair-to-shield and pair-to-ground capacitance unbalance and conductor resistance unbalance also contribute to crosstalk in lesser amounts.

## Inductive Coupling

Electric current flowing in the conductors of the disturbing pair create a magnetic field

which induces an unwanted voltage in conductors of the disturbed pair. To minimize inductive coupling each signal pair is twisted so that the magnetic field resulting from the disturbing pair is reduced and, at the same time, the disturbed pair is made more immune to magnetic fields. To further reduce coupling, the lay length (length of twist) of adjacent pairs is made unequal. Uneven twisting of pairs in which one wire tends to wrap around the other must also be avoided.

In conclusion, crosstalk is an unavoidable but controllable characteristic of telephone wire and cable. It is measured in decibels with typical values in the 90 to 110 dB range at voice frequencies. Crosstalk is minimized through the following steps in cable design and manufacture:

- Control of conductor resistance to minimize resistance unbalance.
- Control of conductor diameter to minimize capacitance and resistance unbalance.
- Control of insulation thickness to minimize capacitance unbalance.
- Control and minimize the dielectric constant of insulation and filling compound to reduce capacitance unbalance.
- Twist all pairs to minimize inductive coupling.
- Vary the lay length (length of twist) for pairs in close proximity to minimize inductive coupling.
- Avoid uneven twisting of pairs (one wire tending to wrap around another) to minimize inductive coupling. 